

ALFALFA PRODUCTIVITY WITH VARYING LEVELS
OF ALFALFA WEEVIL, *HYPERA POSTICA*
(GYLLENHAL), INFESTATION, WEED
INTERFERENCE, AND EXTENDED
GRAZING

BY

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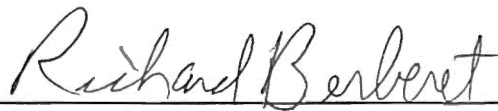
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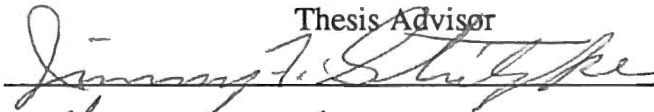
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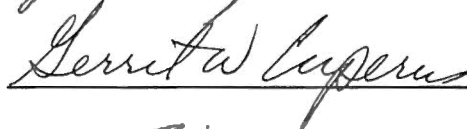
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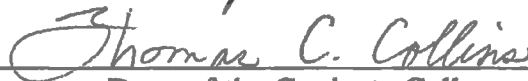
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TABLE OF CONTENTS

Chapter		Page
I.	LITERATURE REVIEW	1
	Literature Cited	8
II.	EFFECTS OF GRAZING AND PESTICIDE APPLICATION ON POPULATION DENSITIES OF THE ALFALFA WEEVIL & ALFALFA PRODUCTION	12
	Introduction	12
	Materials & Methods	13
	Results	15
	Discussion	20
	Literature Cited	22
III.	ALFALFA PRODUCTION WITH VARYING LEVELS OF ALFALFA WEEVIL INFESTATION AND GRASS INTERFERENCE	23
	Introduction	23
	Materials & Methods	24
	Results	25
	Discussion	28
	Literature Cited	30
IV.	POPULATION DYNAMICS OF ALFALFA WEEVIL AND <i>BATHYPLECTES</i> SPP. AS INFLUENCED BY ALFALFA / GRASS MICROHABITATS	31
	Introduction	31
	Materials & Methods	32
	Results	34
	Discussion	35
	Literature Cited	37

LIST OF TABLES

Table	Page
Appendix A	
I. Alfalfa Weevil Egg Numbers ($\bar{X} \pm SE$) with three Grazing Treatments, Chickasha, OK 1990-1992	40
II. Alfalfa Weevil Larval Numbers ($\bar{X} \pm SE$) as Influenced by Pesticide Treatments, Chickasha, OK 1990-1991	41
III. Analysis of Variance (F Statistics) for Alfalfa Stems per 0.1 m ² , Chickasha, OK 1990-1992	42
IV. Alfalfa Stem Numbers ($\bar{X} \pm SE$) for Four Pesticide Treatments and Two Cultivars, Chickasha, OK 1990-1992	43
V. Alfalfa Stem Numbers ($\bar{X} \pm SE$) as Influenced by Three Grazing Treatments, Chickasha, OK 1990-1992	44
VI. Analysis of Variance (F Statistics) for Alfalfa Yield, Chickasha, OK 1990-1992	45
VII. Alfalfa Production (kg/ha) ($\bar{X} \pm SE$) as Influenced by Grazing Treatments, Chickasha, OK 1990-1990	46
VIII. Alfalfa Forage Production (kg/ha) ($\bar{X} \pm SE$) for Pesticide Treatments and Cultivars, Chickasha, OK 1990	57
IX. Yearly Alfalfa Production (kg/ha) ($\bar{X} \pm SE$) for Grazing Treatments, Pesticide Treatments, and Cultivars, Chickasha, OK 1990-1992	48
X. Alfalfa Forage Production (kg/ha) ($\bar{X} \pm SE$) for Pesticide Treatments and Cultivars, Chickasha, OK 1991	49
XI. Alfalfa Weevil Larval Numbers ($\bar{X} \pm SE$) as Influenced by Grazing, Pesticides, and Cultivars Chickasha, OK (30 March 1992)	50

Table	Page
XII. Alfalfa Forage Production (kg/ha) ($\bar{X} \pm SE$) for Pesticide Treatments, and Cultivars, Chickasha, OK 1992	51
XIII. Downy Brome Interference as Influenced by Pesticide Treatments and Cultivars, Chickasha, OK 1992	52
Appendix B	
XIV. Early Season Alfalfa Stem Counts ($\bar{X} \pm SE$) per 0.1 m ² , Chickasha, OK 1990-1992	54
XV. Alfalfa Production (kg/ha) ($\bar{X} \pm SE$) as Influenced by Alfalfa Weevil Infestation and Weed Interference, Chickasha, OK 1990	55
XVI. Alfalfa Production (kg/ha) ($\bar{X} \pm SE$) as Influenced by Alfalfa Weevil Infestation and Weed Interference, Chickasha, OK 1991	56
XVII. Alfalfa Production (kg/ha) ($\bar{X} \pm SE$) as Influenced by Alfalfa Weevil Infestation and Weed Interference, Chickasha, OK 1992	57
XIII. Early Season Alfalfa Stems Counts ($\bar{X} \pm SE$) per 0.1 m ² , Stillwater, OK 1991-1992	58
XIX. Alfalfa Production (kg/ha) ($\bar{X} \pm SE$) as Influenced by Alfalfa Weevil Infestation and Weed Interference, Stillwater, OK 1991	59
XX. Alfalfa Production (kg/ha) ($\bar{X} \pm SE$) as Influenced by Alfalfa Weevil Infestation and Weed Interference, Stillwater, OK 1992	60

LIST OF FIGURES

APPENDIX C

Figure	Page
1. Relationship of Alfalfa Weevil Egg Numbers and Extent of Downy Brome Infestation Adjacent to Alfalfa Plants	62
2. Relationship of Alfalfa Weevil Larval Numbers and Extent of Downy Brome Infestation Adjacent to Alfalfa Plants	63
3. Parasitism of Alfalfa Weevil Larvae by <i>Bathyplectes</i> spp. as Influenced by Alfalfa Cultivars and Extent of Downy Brome Infestation.....	64

CHAPTER I

LITERATURE REVIEW

Alfalfa, *Medicago sativa* (L.), a leguminous perennial that originated near Iran, was introduced to America in the early 1700's (Bolton et al. 1972). Because it provides a natural source of nitrogen and contains high levels of digestible protein, minerals, and vitamins, alfalfa is one of the most economically important forage crops in the United States (Criswell et al. 1991). In the mid-1800's pioneers from Kansas and Colorado brought alfalfa seed with them as they settled in Oklahoma (Chaffin 1950). Since then, alfalfa has been an important commodity to the state and in the last few years it has been grown on over 162,000 ha with production valued at over \$150 million per year (Stark et al. 1990).

In Oklahoma the growing season for alfalfa is typically from early March until October, and under favorable conditions alfalfa producers may take up to six cuttings by utilizing a recommended 28-35 day interval (Criswell et al. 1990). This is the time needed to achieve 10% bloom which coincides with maximum production of crude protein, digestible nutrients, and herbage (Smith 1972).

A major pest of alfalfa, the alfalfa weevil (*Hypera postica* Gyllenhal), was introduced into America from Europe, the Middle East, or perhaps from northern Africa (App & Manglitz 1972). It was first discovered in 1904 near Salt Lake City, Utah (Titus 1910), and spread to 12 western states within 50 years (Evans 1959). This population was later referred to as the western strain to distinguish it from a second population first reported in Maryland and surrounding states in 1951 (Poos & Bissell 1953). The eastern strain spread throughout the Atlantic states and moved west of the

Mississippi river by 1967 (Blickenstaff et al. 1972). It entered the northeast counties of Oklahoma in 1968 from Arkansas and Missouri. The western strain was reported in the panhandle of Oklahoma after entering from Colorado and Kansas. By 1971 the alfalfa weevil was established throughout the state (Berberet et al. 1980). Economic losses have made this an important insect pest to Oklahoma alfalfa producers.

The alfalfa weevil is a holometabolous, univoltine insect that overwinters as eggs and adults in Oklahoma and other southern states. Adults aestivate outside alfalfa fields along fence rows and other uncultivated areas (Berberet et al. 1980). Since the metabolic rate is reduced and development is halted during aestivation, the weevil undergoes a true diapause (Manglitz 1958; Tombes 1964). Temperature and photoperiod appear to be factors controlling diapause. Removal of forage at first harvest causes the soil surface temperature to increase promoting weevil adults to leave the field and diapause. Cool temperatures (below 5 °C) in autumn terminate diapause. Blickenstaff et al. (1972) reported that weevil adults developing from larvae reared *under daylengths of 12.2 hrs. or less did not diapause*. Bland (1971) found the time from adult emergence to oviposition of laboratory-reared weevils decreased as the number of days with short photoperiods (8 hrs. light per 16 hrs. dark) increased. Sexual maturation and oviposition occur following diapause when the adults return to the field in the fall (Litsinger & Apple 1973).

Following diapause, adults aggregate around field borders and migrate into alfalfa about October to November in Oklahoma (Berberet et al. 1980). Taller alfalfa stems with relatively large diameters are preferred for oviposition as they have space for larger egg clusters (VanDenburgh et al. 1966; Norwood et al. 1967). More succulent, hollow stems are preferred over fibrous stems (Hamlin et al. 1949). In Ohio, Niemczyk & Flessel (1970) discovered that most eggs laid in the spring were found in dead stems until growth of new alfalfa reached a height of 10 cm. After selection of an ovipositional site, the female chews a hole in the stem, deposits the

eggs, and seals the hole with fecal material (Manglitz & App 1957; Evans 1959). Sealing the hole is believed to aid in maintaining high relative humidity for successful egg development. Oviposition continues from fall through spring whenever the temperature remains above the required threshold of 1.7 °C (Hsieh & Armbrust 1974).

As eggs are exposed to longer periods of cold weather, few remain viable. In Pennsylvania, egg viability was highest in January and lowest in March (Townsend & Yendol 1968). In Illinois, egg viability was about 80% greater in eggs laid in spring compared with those eggs laid in the fall or winter. In addition, due to more daily temperatures above the threshold for egg laying, the ovipositional period was longer in southern Illinois than northern Illinois (Hsieh & Armbrust 1974). Similarly, with mild temperatures during winters in Oklahoma, egg deposition occurs from November to May (Berberet et al. 1980).

Location of eggs relative to the distance from the soil surface is another important factor contributing to egg viability. Dively (1970) reported the greatest proportion of viable eggs in stubble (75%), while viability was lower in new growth (39%) and bud stage alfalfa (13%). Eggs closer to the soil surface were less likely to be exposed to lethal low temperatures than eggs near stem tips.

Armbrust et al. (1969) found that the egg stage had a higher amount of winter survivorship and was more cold-hardy than the other developmental stages. It was found that the lethal low temperatures for 5 and 10-day-old eggs were -21.9 and -23.8°C, respectively. Morrison & Pass (1974) reported that eggs become more tolerant to cold temperatures as embryogenesis proceeds until the "black head stage" at which point the head capsule may be seen through the chorion. Research by Shade and Hintz (1983) concluded that at this developmental stage embryos are most susceptible to cold temperature. Furthermore, Armbrust et al. (1966) determined that field location, snow cover, severity of winter, and condition of the alfalfa are also factors that influenced egg viability.

Developmental rates of larvae are based on the accrual of (Celsius degree days) CDD above the developmental threshold of 10°C (Hsieh & Armbrust 1974). In Oklahoma, eclosion may begin in January and the peak in larval numbers typically occurs from mid-March to late April (Berberet et al. 1980). In northern Oklahoma peak larval numbers occur with the accumulation of approximately 150-250 CDD from 1 January, and in southern Oklahoma peak larval densities occur with the accrual of 300-400 CDD (Berberet et al. 1978).

After hatching, first instars leave the stem through the oviposition puncture site and crawl upward to find growing terminals where they feed and attain some protection from the weather (Manglitz & App 1957). Early instars feed on the meristematic buds and cause "ragging" of the leaves as they emerge. The third and fourth instars crawl from the terminals and feed on mature leaves. The fourth instars then crawl or drop to the ground and spin silken cocoons for pupation (Evans 1959). In Maryland, Poos & Bissell (1953) found that cocoons may sometimes be located between leaves of alfalfa. *In Oklahoma pupae are found from mid-March to mid-May with the normal duration of pupation occurring approximately about 10 days (Berberet et al. 1980).* Newly emerged adults remain in fields until the first harvest and exit the field to aestivate as temperatures increase following cutting.

The larva is the main damaging stage of the alfalfa weevil. Direct feeding injury to the terminals, buds, and leaves results in defoliation and stunting of the first crop in southern states. Yield reductions in the second crop result from residual effects of feeding injury. In addition, feeding injury causes reduced stem density, growth, and moisture content of alfalfa (Godfrey & Yeargan 1989). In Oklahoma, about 188 kg/ha are lost at first harvest with each addition of 1 larva per stem (Berberet et al. 1980). Reduced photosynthesis and growth results in stunting, which is reflected in reduced yield to the second harvest. This residual effect causes about 160 kg/ha in losses to the second crop for each addition of one larva per stem (Berberet et al. 1980)

In addition to feeding of larvae, adults sometimes damage the first crop and delay growth of the second crop. Usually the adult damage is minor because populations are lower and feeding time is shorter. However, Bjork & Davis (1984) found that five newly emerged adults cause as much damage as 25 larvae, and that newly emerged adults feed more than adults returning from aestivation.

Maintaining alfalfa stands with few weeds is important in producing high quality forage because weeds and grasses are much lower in IVDDM (in vitro digestible dry matter) and CP (crude protein) (Temme et al. 1979). New alfalfa stands are quite competitive with weeds, but as stands age they become less competitive to weed establishment. Reduced stem numbers opens the plant canopy and provides space for weeds to establish. Insect defoliation may indirectly lead to increased weed establishment. Defoliation reduces the competitiveness of alfalfa with weeds, delays alfalfa growth, and allows time for germination and emergence of weeds (Buntin 1989). In California, Summers & Newton (1989) reported that herbivores like the Egyptian alfalfa weevil, *Hypera brunneipennis* Bohman, pea aphid, *Acyrthosiphon pisum* (Harris), and foliage-feeding lepidoptera also give competitive advantage to summer annual weeds. In Oklahoma, the rate of weed encroachment is increased as alfalfa is stressed by alfalfa weevil feeding (Berberet et al. 1987). Woodall (1987) concluded that as alfalfa stands decline to less than 20 stems per 0.1 m² the competitive advantage is shifted to the weeds.

Weeds often serve as ovipositional sites for the alfalfa weevil in alfalfa fields. Females may lay eggs in henbit, *Lamium amplexicaule* (L.), and shepherdspurse, *Capsella bursa-pastoris* (L.) Medic. (Ben Saad & Bishop 1969). In addition, alfalfa plots highly infested with henbit had more terminal damage than plots with low henbit numbers (Waldrep et al. 1969). Weeds may serve as alternate sites for egg deposition and are not used as a food by larvae. After hatching, the larvae must crawl to alfalfa plants in order to find proper feeding locations.

To more efficiently regulate populations of the alfalfa weevil, integrated control programs have been implemented in most states. The control programs employed in Oklahoma involve winter grazing or late fall cutting, biological control, tolerant cultivars, and chemical insecticides. Winter grazing to remove fall growth of alfalfa reduces habitat and oviposition sites for adults and destroys many eggs laid in the early fall with a subsequent reduction in larval numbers. Senst & Berberet (1980) found the numbers of fall-laid eggs are reduced by 60% with winter grazing. In Louisiana, Whitford & Quisenberry (1990) found that delaying the last harvest resulted in less fall growth and fewer suitable oviposition sites.

Bathyplectes curculionis (Thomson) and *B. anurus* (Thomson) are endoparasitic wasps that aid in control of the alfalfa weevil (Berberet et al. 1978). Primarily first and second weevil instars are parasitized and killed after they spin their silken cocoons. The parasitic larva then forms its cocoon within the weevil cocoon (Brunson & Coles 1968). *B. curculionis* is bivoltine and the second generation overwinters as a prepupa with pupation occurring the following spring (Chamberlin 1926). The ability of *B. curculionis* to regulate populations of the eastern strain of *H. positca* is reduced by encapsulation of eggs by cells in the hemolymph (Puttler 1967; Berberet & Gibson 1976).

B. anurus also oviposits in small larvae but is univoltine. It forms its cocoon inside that of the weevil, but in the fall the parasite pupates and overwinters as a diapausing adult which emerges the following spring. Two characteristics of *B. anurus* may aid its effectiveness as a natural enemy. First, it appears that eastern strains of the alfalfa weevil larvae do not encapsulate its eggs (Puttler, 1967). Second, diapausing prepupae can flip inside the cocoon and cause the cocoon to move (Brunson & Coles 1968). This action may aid in avoiding unfavorable microhabitats and hyperparasites by moving cocoons to protected locations at the soil surface (Day 1970). Although it

possesses these characteristics, *B. anurus* has not spread throughout Oklahoma as efficiently and has not been as successful as *B. curculionis*.

In Oklahoma, 'Cimarron' and 'WL 318' are examples of alfalfa cultivars that have some tolerance to weevil damage (Mulder 1990). Under weevil infestations, forage production by these cultivars is attributed to vigorous growth and increased lateral branching after feeding injury. Several glandular-haired annual *Medicago* spp. have shown some degree of antibiosis. The amount of feeding and oviposition damage was reduced on these glandular species. However, genes from these annual spp. have not been successfully transferred to perennial *Medicago* spp. (Johnson et al. 1980).

With integrated control, the use of chemical insecticides may be reduced. Insecticides are an excellent way to control infestations but may be toxic to both the applicator and beneficial insects. The key to chemical control is proper timing and knowledge of weevil biology. In New York, spraying field borders in the fall as adults return from aestivation has proven to be effective in lowering spring larval populations (Armbrust et al. 1966). Norris et al. (1984) found that alfalfa was more competitive with weeds when populations of the Egyptian alfalfa weevil were reduced with insecticides. In Oklahoma, spraying with insecticides in the spring before peak alfalfa weevil numbers occur significantly reduces larval populations below the economic threshold of 1.5 - 2.0 larvae per stem (Berberet et al. 1981) resulting in decreased feeding injury (Berberet & McNew 1986).

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CHAPTER II

EFFECTS OF GRAZING AND PESTICIDE APPLICATION ON POPULATION DENSITIES OF THE ALFALFA WEEVIL & ALFALFA PRODUCTION

Introduction

Grazing alfalfa in winter is a way to utilize fall growth while reducing alfalfa weevil numbers (Senst & Berberet 1980) and cool season weed interference in the spring. In Oklahoma, Stark et al. (1990) reported that farmers left cattle on alfalfa for 1 to 4 months. However, as grazing period increase the amount of damage to crowns also increases as a result of trampling by cattle. This may lead to secondarily induced crown and root rot. Berberet et al. (1980) reported that flash-grazing alfalfa for 2-3 weeks when the soil was frozen or dry in December and January was a useful cultural practice for reducing numbers of eggs and resulting populations of weevil larvae in the spring. This grazing schedule showed no detriment to alfalfa production.

In Oklahoma, egg deposition occurs from October to the following May. Winter grazing not only destroys eggs but removes available ovipositional sites. By reducing egg numbers in the winter it is possible to delay occurrence of peak larval populations and feeding damage in the spring. The delay in peak larval numbers may result in less need for insecticide applications. As an added benefit, winter annual weeds such as downy brome and cheat (*Bromus* spp.), and mustards (*Brassica* spp.) may be reduced by delaying their growth until alfalfa becomes more competitive later in winter.

The objectives of this experiment were: 1) to describe the effects of extended-

The objectives of this experiment were: 1) to describe the effects of extended-grazing on alfalfa weevil populations and alfalfa production; 2) to compare flash-grazing and extended-grazing as management options for the alfalfa weevil; 3) to document the combined and individual effects of alfalfa weevils and weeds on alfalfa productivity under varied grazing treatments.

Materials & Methods

This experiment was conducted for 3 years under irrigation at the Southcentral Oklahoma Research Station at Chickasha, OK, with grazing treatments initiated during fall in 1989, 1990, and 1991. Two alfalfa cultivars 'Cimarron' (multiple-pest resistant) and Oklahoma common 'OK08' (no pest resistance) were sown in the fall of 1987. These cultivars were used because of the potential for differences in rate of alfalfa stand decline under treatments imposed in this experiment. A split-plot experimental design was used with four replications of three grazing treatments (main plots = 10 x 146m). Grazing schedules consisted of "extended-grazing" (October - December), "flash-grazing" (2-3 wks in December-January when the soil was dry or frozen), and "ungrazed". Grazing treatments were first imposed in 1989. Subplots (10 x 20 m) were arranged in a 2 x 2 x 2 factorial across each main plot. Treatments on subplots included the cultivars ('Cimarron' or 'OK08'), herbicide application (sprayed vs. unsprayed), and insecticide application (sprayed vs. unsprayed).

The herbicide terbacil (@ 0.56 kg[AI]/ha) was applied in March to control winter annual weeds. Carbofuran insecticide (@ 1.12 kg[AI]/ha) was applied in mid-February or early March to control naturally occurring populations of alfalfa weevil larvae. The resulting pesticide treatments included: 1) insecticide-only; 2) herbicide-only to remove competition from downy brome (*Bromus tectorum* L.) and shepherdspurse, (*Capsella bursa-pastoris* L.) in the spring; 3) both insecticide and herbicide to control weeds and weevils; 4) unsprayed to allow weed and weevil

infestations. In the summer of 1989, downy brome and shepherdspurse were overseeded at 19 and 61 seeds/0.1m², respectively, to insure the potential for cool-season weed competition with alfalfa. In June of each year, sethoxydin herbicide (@ 0.28 kg[AI]/ha) was applied over the experiment to remove crabgrass (*Digitaria* spp.). Populations of blue alfalfa aphid, *Acyrhosiphon kondoi* (Shinji), and pea aphid, *A. pisum* (Harris), were monitored and were treated when necessary with chlorpyrifos (@ 0.20 kg[AI]/ha) to prevent aphids from confounding the results. At this rate of application alfalfa weevil numbers were not significantly reduced.

Samples of alfalfa foliage were taken to estimate alfalfa weevil egg numbers shortly after grazing was terminated (January) and eclosion became extensive (March). Timing of samples were based on weekly observations of egg numbers in an adjacent alfalfa field. Three, 0.025 m² samples were taken at random from each cultivar and grazing treatment per replicate. Alfalfa crowns were cut at ground level and forage, dead (fall growth) and living crown growth, was bagged. Eggs were extracted from alfalfa stems using the blender method as described by Pass & VanMeter (1966).

Larval populations were sampled during growth of the first crop (March, April) based on accumulation of (Celsius degree days) CDD and feeding damage. Sampling was timed to determine peak larval numbers. Within each subplot, 25 stems were pulled at random and bagged. Larvae were retrieved from the samples with Berlese funnels and stored in alcohol until counted. Instars were delineated based on head capsule sizes.

At initiation of the experiment, three permanent quadrats (0.5 x 1 m) were located randomly in the corners of each subplot to monitor weed interference and production of alfalfa and weed biomass. Stand persistence and yield of the first crop were also estimated from these quadrats. Within the quadrat alfalfa stems, downy brome and henbit plants were recorded in March of each year. First harvest yield was estimated by hand clipping forage within each quadrat, separating alfalfa from weeds,

and bagging each separately. Samples were oven dried, weighed and dry matter production (kg/ha) was determined.

Before each harvest, the percent composition of weeds in forage was visually estimated. These percentages were used to calculate the weight of weeds in alfalfa yield (kg/ha). Harvests were conducted at approximately 30 day intervals (10% bloom) using a Carter harvester. A (1 x 5m) green weight sample was cut and weighed. From that sample a 200-500g subsample was removed for drying to determine the moisture content. Dry weight of forage was calculated and subdivided into weed and alfalfa components. Stem numbers of alfalfa was also estimated in each alfalfa crop by counting stems in five quadrats (15 x 76cm) per subplot.

In the context of this investigation, the term "year" refers to the time from initiation of grazing in the fall, to the last harvest in late summer of the next year. To simplify results only the estimated peak egg and larval numbers for each year are reported. Also, for each year stem counts in the first crop and alfalfa yield of the first two harvests are presented. Data from these harvests were used to show the effect of grazing and alfalfa weevil infestation on alfalfa production. After the second crop the residual effect from weevil damage was no longer evident. All data were subjected to analysis of variance procedure by sampling date (SAS Institute, 1991). Mean separation were determined with the least significant difference (LSD) test $\alpha = 0.05$ level of probability (Steel & Torrie 1980).

Results

First Year (1989-1990)

No significant differences in egg numbers resulted for cultivars ($F = 0.18$; $df = 1,63$; $P = 0.68$) and no interactions resulted, so effects of grazing were pooled. After grazing was completed (04 January), significant differences among grazing

treatments were detected ($F = 52.50$; $df=2,6$; $P < 0.01$) with average egg numbers ranging from 48 ± 4.9 per 0.1m^2 in flash-grazing treatments to 132.7 ± 16.8 per 0.25m^2 in ungrazed plots. Both flash-grazing and extended-grazing treatments significantly reduced egg numbers compared to ungrazed treatments (Table I).

Larvae were sampled on 05 April. This was the only sampling date for larvae because the experimental area was subsequently sprayed with chlorpyrifos to prevent serious damage by the blue alfalfa aphid. Larval numbers were not significantly different among grazing treatments ($F = 4.77$; $df = 2,6$; $P = 0.06$) or cultivars ($F = 1.99$; $df = 1,63$; $P = 0.16$). Application of carbofuran resulted in a significant reduction in larval numbers ($F = 36.38$; $df = 1,63$; $P < 0.01$). Numbers ranged from 2.7 ± 0.5 larvae per 25 stems in plots receiving both herbicide + insecticide to 16.0 ± 1.9 larvae per 25 stems without pesticides (Table II).

Analysis of variance (F statistics) for stem numbers are located in Table III. Means for stem counts are found in Tables VI and V. Initial estimates of stem numbers (22 March) indicated no significant differences among grazing, or pesticide treatments. However, stem numbers in 'Cimarron' were significantly greater than in 'OK08'. This may have occurred because 'Cimarron' possesses some tolerance for the alfalfa weevil.

First harvest yields (14 May) were significantly different among grazing treatments, pesticide treatments, and cultivars. F statistics for alfalfa yield are located in Table VI and means for yield (kg/ha) are provided in Tables VII & VIII. Yield was highest with flash-grazing ($3,201 \pm 75$ kg/ha) and was significantly reduced to $2,338 \pm 76$ in the extended-grazing treatment (Table VII). Alfalfa production was significantly higher with the herbicide + insecticide treatment than in the other pesticide treatments (Table VIII). Also 'Cimarron' yield was significantly greater than 'OK08'.

At the second harvest (13 June), no significant differences in yield occurred among pesticide treatments. There was no evidence of residual effects from alfalfa

weevil infestation. No significant differences resulted in yearly alfalfa production among grazing treatments (Table IX). Yield for the year was greatest in the herbicide + insecticide treatment. In addition, 'Cimarron' produced significantly greater yield than 'OK08'.

Second Year (1990-1991)

Egg numbers were low throughout the experimental area. At the time when eclosion began (28 February), no significant differences among grazing treatments were detected ($F = 1.51$; $df = 2,6$; $P = 0.29$) (Table I). Egg numbers per 0.1m^2 ranged from 4.2 ± 3.0 (flash-grazing) to 17.7 ± 8.0 (ungrazed). No significant differences in egg numbers resulted for cultivars ($F = 1.73$; $df = 1,63$; $P = 0.22$).

Estimated peak larval populations occurred about 06 April. There were no significant differences in larval numbers between cultivars ($F = 0.38$; $df = 3,63$; $P = 0.54$) or among grazing treatments ($F = 4.77$; $df = 2,6$; $P = 0.40$) (Table II). However, there were significantly lower numbers of larvae ($F = 10.78$; $df = 3,63$; $P < 0.01$) where insecticide was applied. Larval numbers ranged from 6.5 ± 1.6 per 25 stems (sprayed) to 20.7 ± 3.6 per 25 stems (unsprayed) (Table II).

Alfalfa stem counts were taken on 28 March. Significant differences in stem numbers were detected among grazing treatments and between cultivars (Table III). Significantly greater stem numbers occurred in ungrazed (19.7 ± 3.8 per 0.1m^2) and flash-grazing treatments (19.0 ± 3.6 per 0.1m^2) than in the extended-grazing treatments (15.5 ± 3.6 per 0.1m^2) (Table IV and V).

At first harvest (30 April), yields were significantly different among grazing and pesticide treatments and between cultivars (Table VI). Significantly greater yields occurred in flash-grazing and ungrazed treatments as compared with the extended-grazing treatment (Table VII). Yield of 'Cimarron' was significantly greater than for 'OK08' (Table X). The herbicide + insecticide treatment had significantly higher

yields than herbicide only and insecticide only treatments. Yield was significantly greater when pesticides were applied in comparison with unsprayed treatments (Table X).

The second harvest (05 June) yields were significantly different between cultivar and pesticide but not among grazing treatments. 'Cimarron' provided greater yield than 'OK08' while herbicide + insecticide and insecticide only treatments produced significantly more yield than herbicide only and unsprayed treatments (Table X). Alfalfa production for the year was significantly greater in flash-grazing and ungrazed treatments than for extended-grazing treatments. Also, yields were significantly greater with insecticide or herbicide treatments than for the unsprayed treatment (Table IX).

Third Year (1991-1992)

Egg samples taken on 05 February numbers were significantly different among grazing treatments ($F = 13.10$; $df = 2,6$; $P = 0.01$) (Table I). Both extended-grazing and flash-grazing treatments reduced egg numbers when compared with the ungrazed treatment. Egg numbers ranged from 26.2 ± 6.2 (extended-grazing) to 116.7 ± 19.0 (ungrazed).

The estimated peak in larval numbers occurred about 30 March. There was a significant pesticide x grazing interaction for larval numbers. The probable reason for this interaction was the difference in variation of larval counts among pesticide treatments within each grazing treatment. Within extended-grazing, the pesticide treatments that included no insecticides had the highest populations of weevil larvae (103.6 ± 11.2 per 25 stems) throughout the experiment. In contrast the herbicide + insecticide treatment within extended-grazing had nearly the lowest numbers (33.3 ± 4.4 per 25 stems) (Table XI). Means for larval numbers were similar for pesticide treatments within the flash-grazing treatment but the range was much smaller. The range of values for mean larval numbers in pesticide treatments was even smaller for

the ungrazed treatment. Larvae were significantly more numerous in 'Cimarron' than 'OK08' for both the flash-grazing and ungrazed treatments (Table XI).

Stem numbers were recorded on 26 March and were significantly different among pesticide treatment and between cultivars (Table III). Mean stem numbers had declined to 7.9 ± 0.3 ('OK08') and 12.3 ± 0.3 for ('Cimarron') (Table IV). Stems per 0.1m^2 were greatest in the herbicide + insecticide treatment and lowest in the unsprayed treatments. (Table IV).

In April the first crop was destroyed by hail, and there was no opportunity for yield comparisons among treatments. The first opportunity to take a harvest (18 May) actually occurred in the second crop. Yields were significantly different among grazing and pesticide treatments and between cultivars (Table VI). Significantly greater yields occurred in herbicide + insecticide and herbicide only treatments in comparison with the unsprayed treatment (Table XII). 'Cimarron' yield was also greater than 'OK08' (Table XII).

At second harvest (13 July) yields were not significantly different among grazing treatments. However, yield was significantly different among pesticide treatments and between cultivars (Table XII). Yields ranged from $(2,672 \pm 140 \text{ kg/ha})$ in the herbicide + insecticide treatment to $(2,401 \pm 145 \text{ kg/ha})$ in the unsprayed treatment.

Significant differences were detected for yearly alfalfa production among pesticide treatments and between cultivars (Table IV). Yield was significantly reduced in the unsprayed treatment compared to the other pesticide treatments. Alfalfa yield was also greater in 'Cimarron' than in 'OK08' (Table IX).

In addition, downy brome plants per 0.1 m^2 was determined. Brome plants were significantly less numerous in the herbicide + insecticide and herbicide only treatments than in the insecticide only and unsprayed treatments. The greatest amount of brome encroachment occurred in the unsprayed treatment ($2.3 \text{ plants}/0.1\text{m}^2$). Due

to less stand decline in 'Cimarron' subplots, fewer downy brome plants became established than in 'OK08' (Table XIII).

Discussion

During November and December, when alfalfa weevil ovipositional activity was high, both extended-grazing and flash-grazing treatments resulted in reduced egg densities in comparison to the ungrazed treatment. These results were similar to those of Senst & Berberet (1980), who reported about 60% reduction of fall-laid eggs by flash-grazing. In each year of the experiment, egg numbers in the two grazing treatments were not significantly different and it appeared that 2-3 weeks of grazing in winter lessened egg populations as efficiently as 2-3 months of grazing in the fall. This is important because reducing the time cattle spend in fields may decrease potential for injury to alfalfa crowns caused by trampling of livestock.

Although egg populations were significantly reduced by extended-grazing and flash-grazing treatments, estimated peak larval numbers were not reduced. However, larval numbers were reduced in grazing treatments at the first date of sampling in 1991 and 1992. It is expected that grazing treatments in the fall and winter would have their greatest effect as larvae began to hatch because those larvae come from eggs deposited in the fall. Subsequent hatching includes larvae from eggs laid after grazing was terminated and may not show as clearly the effects of grazing.

Stand decline was greater in 'OK08' than 'Cimarron' over the years of this experiment. By the second year (1991), preharvest stem counts were 15.5 per 0.1m² in extended-grazing plots. Woodall (1987) found that stem counts below 20 stems per 0.1m² to be the point in which alfalfa is no longer able to prevent weed establishment. The relationship of weed encroachment and weevil damage was evident by the numbers alfalfa stems and brome plants per 0.1m². Alfalfa stem density was lowest with combined weed and weevil infestation. In addition, the numbers of downy brome

plants were greatest where no pesticides were applied. It was apparent that extended-grazing resulted in lower yield at first harvest of alfalfa, but did not reduce yearly production. From the beginning of the experiment, alfalfa production was greater for 'Cimarron' than for 'OK08'.

In conclusion, Senst & Berberet (1980) reported that reducing egg numbers in the winter lessened larval numbers in the spring; however, in this experiment there were no differences in larval numbers at peak population numbers resulting from grazing treatments. It appears that extended-grazing may be deleterious to alfalfa production at first cutting. This is important since many Oklahoma farmers use grazing as a cultural practice for several months in the fall (Stark et al. 1990). Yield at first harvest was lower when extended-grazing was implemented, but total alfalfa production per year was not significantly reduced by this management practice. From the results of this experiment, it appears that flash-grazing may provide reduced alfalfa weevil numbers while maintaining maximum alfalfa production.

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CHAPTER III

ALFALFA PRODUCTION WITH VARYING LEVELS OF ALFALFA WEEVIL INFESTATION AND WEED INTERFERENCE

Introduction

In Oklahoma, the alfalfa weevil (*Hypera postica* Gyllenhal) and *Bromus* spp. are important pests that lower alfalfa stand persistence and forage production (Latheef et al. 1992). Feeding damage by the alfalfa weevil reduces yield at first harvest by an average of 1,000 kg/ha (Berberet et al. 1980). Due to a reduction in stem numbers and plant vigor, residual effects often reduce yield of the second crop (Berberet et al. 1980). Cool season grasses (*Bromus* spp) decrease alfalfa productivity by competing for light, temperature, and moisture (Pike & Stritzke 1984). As stands thin, these grasses and warm season species such as foxtail, *Setaria* spp., and crabgrass *Digitaria* spp. also become competitive and further reduce alfalfa production.

Weed establishment is increased when feeding injury by the alfalfa weevil stresses alfalfa plants (Berberet et al. 1987; Godfrey & Yeargan 1987). The combined effects of the alfalfa weevil and weeds were found to cause greater losses in production than occurred with the sum of pest effects taken individually (Berberet et al. 1987). An important factor in maintaining productive stands is timely application of herbicides and insecticides (Latheef et al. 1988). The objectives of these experiments were to determine the extent that alfalfa weevil damage may increase establishment of cool-season grasses. Also studied was the establishment of warm season grasses competing

with alfalfa having been stressed by weevil damage and cool season weed interference earlier in the growing season.

Materials and Methods

Two experiments were conducted from 1990-1992 on established alfalfa stands seeded at 11.9 kg/ha with a Brillion seeder in September 1987. Experiment I was located at the Southcentral Research Station at Chickasha, OK, on an irrigated field of the cultivar 'OK08'. Experiment II was conducted at Stillwater, OK, on a nonirrigated field of 'Cimarron' alfalfa.

Two levels each of cool season grass interference, warm season grass interference, and alfalfa weevil infestation were arranged on plots in a randomized complete block design with a 2 x 2 x 2 factorial arrangement of treatments. For each treatment combination a pesticide was employed to reduce the pest population to a low level for comparison to a high level of infestation on unsprayed plots. Low levels of cool season grasses (downy brome and shepherdspurse *Capsella bursa-pastoris* (L.) Medic.) were obtained by application of terbacil WP (0.56 kg[AI]/ha) in February. Low levels of warm-season grasses (foxtails and crabgrass) were obtained by application of sethoxydin (0.28 kg[AI]/ha) in June for comparison with plots receiving no sethoxydin. Low and high levels of alfalfa weevil infestation were obtained with application of carbofuran (1.12 kg[AI]/ha.) in late February, for comparison with plots having no insecticide. Applications of these pesticides resulted in the following pest combinations: low vs. high weevil infestation in conjunction with 1) warm-season grasses, 2) cool season grasses, 3) warm and cool season grasses, and 4) no grasses. To increase the likelihood of weed competition, both experiments were overseeded with downy brome at 50 seeds/43 m². Crabgrass was also seeded at 7.3 and 14.5 kg/ha for experiment I and II, respectively. When needed, chlorpyrifos (0.21 kg[AI]/ha) was

applied over the entire experiment to prevent damage by the blue alfalfa aphid, *Acyrtosiphon kondoi* (Shinji), and pea aphid, *A. pisum* (Harris).

Alfalfa weevil larvae were sampled in the first crop based on the accumulation of (Celsius Degree Days) CDD from 01 January to estimate peak larval populations. In each plot, 25 stems were pulled at random for retrieval of larvae. Larvae were extracted from alfalfa with standard Berlese funnels for counting and instars were delineated based on head capsule sizes.

At first harvest (early May) heights of 20 alfalfa stems and up to 20 brome stems were measured per plot and alfalfa stem counts were made within three random quadrats (50 x 76 cm) per plot. Three quadrats were clipped by hand and alfalfa, brome, and broadleaf weeds were bagged separately for drying. Dry weights of alfalfa and weed biomass (kg/ha) was determined per plot .

Before each subsequent harvest, the percent composition of weeds in forage was visually estimated. These percentages were used to calculate the weight of weeds in alfalfa yield (kg/ha). Harvests were conducted at about 30 day interval (10% bloom) using a Carter harvester. A (1 x 5m) green weight sample was cut and weighed. From that sample a 200-500g subsample was removed for drying to determine moisture content. Dry weight of forage was calculated and subdivided into weed and alfalfa components. Stem numbers of alfalfa was also estimated in each alfalfa crop by counting stems in five quadrats (15 x 76cm) per subplot.

All data were subjected to analysis of variance procedures by sampling date (SAS Institute, 1991). Mean separation was determined with the least significant difference (LSD) test at $\alpha = 0.05$ level of significance (Steel & Torrie 1980).

Results

Experiment I: Chickasha

1989-1990 Year. Alfalfa weevil larvae were sampled on 05 April. Significant differences in larval numbers occurred between insecticide treatments ($F = 38.72$; $df = 16,21$; $P < 0.05$). Plots treated with carbofuran had significantly fewer larvae per 25 stems (6.6 ± 1.2) than those not sprayed (25.8 ± 2.6).

No significant differences in stem numbers were detected among weed infestation treatments or between levels of weevil infestation (Table XIV). At first harvest (15 May), alfalfa yields were not significantly different between weevil infestation levels, but they were significantly different among weed infestation level within each level of weevil infestation (Table XV). Among weed infestations in combination with high weevil populations, the greatest alfalfa yield was achieved with no grasses (both herbicides) ($2,657 \pm 197$ kg/ha). Significantly lower alfalfa yields resulted when both high levels of both warm + cool season grasses were present ($1,846 \pm 172$ kg/ha) (Table XV). Yield from treatment combinations that included low weevil populations ranged from ($1,881 \pm 172$ kg/ha) with cool season grasses to ($3,060 \pm 157$ kg/ha) without grass infestation (Table XV).

Yearly production was not significantly reduced by weevil infestation. No significant differences in yield were detected among weed infestations combined with high weevil populations, but were differences were detected in treatment combinations having low weevil populations. Alfalfa yield was lowest when high levels of cool season grass infestation were permitted (Table XV).

1990-1991 Year. In the second year of the experiment (1991) the peak in alfalfa weevil larval numbers occurred about 06 March. There was no apparent effect of weed infestation on weevil numbers. They were significantly lower in plots treated with carbofuran (7.6 ± 1.3 larvae per 25 alfalfa stems) than in untreated plots (44.5 ± 4.3 larvae per 25 alfalfa stems) ($F = 83.36$; $df = 16,21$ $P < 0.05$).

Stem numbers were estimated on 28 March. Stems per 0.1m^2 were reduced from the previous year but no significant differences among any pest combinations

resulted (Table XIV). No significant differences were detected in alfalfa yield at first harvest or yearly production (Table XVI).

1991-1992 Year. The peak in alfalfa weevil larval numbers occurred approximately 20 March and significant differences were detected between insecticide treatments ($F = 83.72$; $df = 16,21$ $P < 0.05$). Without insecticide larvae per 25 stems averaged 159.0 ± 7.2 compared with 26.4 ± 2.0 in sprayed plots.

Estimates of stem numbers were made on 22 March. No significant differences in stem numbers per 0.1 m^2 were detected among the combinations of weed and weevil infestations (Table XIV).

Yields were not significantly different among levels of grass infestation at first harvest (22 May) or for yearly production. However, yields increased at first harvest when weevil populations were low in combination with cool season grasses and no grass infestation (Table XVII).

Experiment II: Stillwater

1990-1991. Peak larval densities occurred about 07 April and significant differences were detected between insecticide treatments ($F = 144.37$; $df = 16,21$; $P < 0.05$). Larvae per 25 stems averaged 4.2 ± 0.8 with insecticide treatment compared with 62.6 ± 4.6 in unsprayed plots.

Stem numbers were estimated on 26 March. No significant differences were detected among combinations of pest infestations (Table XVIII). At first harvest (01 May) no differences in yield were detected between weevil infestation levels. Differences in alfalfa yield did occur among levels of grass infestation in combination with high populations of weevils (Table XIX). Yield was significantly reduced with high levels of cool season grass infestation.

1991-1992 Year. Peak alfalfa weevil peak larval numbers occurred about 20 March. The only significant difference resulted between insecticide treatments ($F = 235.99$; $df\ 16,21$; $P < 0.05$). Carbofuran treated plots averaged 38.3 ± 3.1 larvae per 25 stems while unsprayed plots had an average 121.8 ± 7.2 larvae per 25 stems.

Significant reductions in stem per $0.1\ m^2$ were detected in comparison of weevil infestation levels. Greater stems per $0.1\ m^2$ was evident with low weevil populations (Table XVIII). No significant differences in stem numbers were detected among levels of weed infestation (Table XVIII).

At first harvest (30 April) significant differences in yield were detected between levels of weevil infestations. Alfalfa yields were significantly reduced when high weevil populations occurred as compared with low weevil populations (Table XX). Within each level of weevil infestation, there were significant differences in yields among levels of grass infestation (Table XX). No significant differences in yearly production resulted among levels of grass infestations (Table XX).

Discussion

In both experiments, use of carbofuran reduced alfalfa weevil larval numbers below the economic threshold of 1.5 - 2.0 larvae per stem (Berberet et al. 1981). Application of the herbicides terbacil and sethoxydin appeared to have no deleterious effects on larvae. High infestation levels of cool season grasses appeared to have no effect on weevil numbers. This is not in agreement with results of Norris et al. (1984) who reported lower numbers of Egyptian alfalfa weevil, *Hypera brunneipennis* (Bohman), in alfalfa with heavy annual weed interference.

Alfalfa stem numbers were not reduced by the presence of cool or warm season grass competition in either experiments. However, by 1992 high levels of weevil infestation resulted in decreased stems at Stillwater. It is likely that within another year, weed competition will be a major factor in differential stand decline in both

studies because alfalfa stem counts are well below 20 stems per 0.1m². Woodall (1987) concluded that this is the stand density where alfalfa is no longer an effective competitor with weeds.

At Chickasha yield has not been significantly reduced by weevil infestation. In 1992 it was expected that differences in yield would occur in yield due to weevil damage. However, a hail storm destroyed the first crop before yield estimates could be made. The first harvest was actually taken on the second crop. Since there was a residual effect for weevil infestation, it is hypothesized that differences would have been more evident had the first crop not been destroyed.

At Stillwater, removal of alfalfa weevil populations greatly increased yield at first harvest and for the year. Yield was lowest at first harvest when high populations of weevils occurred in conjunction with warm + cool season grasses. The reduced yield resulted from stress caused by the alfalfa weevil enabling warm + cool season grasses to compete more effectively with alfalfa.

In conclusion, control of the alfalfa weevil improved stand persistence and provided yield savings. Weevil populations were not reduced by herbicide application or weed interference. Alfalfa remained competitive and prevented extensive weed establishment until 1992. Finally, damage by the alfalfa weevil had been the largest contributing factor to stand decline and yield reduction and appears to indirectly increase weed establishment.

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CHAPTER IV

POPULATION DYNAMICS OF ALFALFA WEEVIL
AND *BATHYPLECTES* SPP. AS INFLUENCED BY
ALFALFA / GRASS MICROHABITATS

Introduction

Limiting winter-annual weed interference is important to maintaining alfalfa stands (Peters & Linscott 1988). The extent of weed infestation is often increased with feeding damage caused by the alfalfa weevil (*Hypera postica* Gyllenhal) because of reduced competitiveness of alfalfa (Woodall 1987). Ben Saad & Bishop (1969) reported on the frequency of alfalfa weevil oviposition in henbit (*Lamium amplexicaule* L.) and shepherdspurse (*Capsella bursa-pastoris* (L.) Medic). Infestation by henbit was highly correlated with increased feeding damage by alfalfa weevil larvae (Waldrep et al. 1969). In Kentucky and California fewer alfalfa weevil larvae were found in weed-free vs. weedy alfalfa (Wolfson & Yeargan 1983, Norris et al. 1984). However, Berberet et al. (1987) reported lower alfalfa weevil larval numbers in 1 year of a 5 year experiment when downy brome (*Bromus tectorum* L.) interference increased. Similarly, in Idaho, Piemeisel (1951) reported lower numbers of beet leafhoppers (*Eutettix tenellus* Baker) in fields highly infested with downy brome.

In addition to effects on populations of arthropod herbivores, weeds in crops provide habitats for predators and parasitoids (Altieri & Hitch 1979). In Georgia, parasitism of *Helicoverpa zea* (Boddie) eggs by *Trichogramma* spp. was 2.8 times greater in intercropped fields of soybeans and corn than in soybean monocultures.

Also, predators of the green peach aphid (*Myzus persicae* Sulzer) were more numerous in weedy collard plots.

The first objective of these experiments was to determine alfalfa weevil egg and larval numbers in microhabitats of alfalfa with varying amounts of downy brome interference. The second was to determine the prevalence of parasitism of weevil larvae by *Bathyplectes* spp. in alfalfa with high (estimated weed composition in forage greater than 50%) and low (weed composition less than 10%) downy brome interference.

Materials and Methods

The experimental area was within a larger alfalfa management experiment currently in the third year of investigation. Therefore, the larger experiment is described below in order to clarify the experimental design and sampling used for the microhabitat studies. Two alfalfa cultivars 'Cimarron' (multiple-pest resistant) and 'OK08' (Oklahoma common) were sown 17 September 1987 in a split-plot design with four replications. The main plots (9 x 146m) were composed of three grazing schedules: 1) extended-grazing from October - December, 2) flash-grazing for 2-3 weeks in December or January, and 3) ungrazed. Eight subplots (9 x 18m) were positioned within each main plots with a 2 x 2 x 2 factorial arrangement of treatments including the cultivars identified above, insecticide (carbofuran) vs. no insecticide, and herbicide (terbacil) vs. no herbicide. Sampling for this part of the experiment was conducted in ungrazed alfalfa that had received no insecticide. The herbicide vs. no herbicide treatments were sampled to obtain estimates of alfalfa weevil numbers and parasitism by *Bathyplectes* spp. with varied levels of weed interference.

Experiment I. Alfalfa weevil eggs were sampled 20 February, 1992 in specific microhabitats within experimental plots. Two samples (one alfalfa plant each) were

taken for each of four levels of downy brome interference in each cultivar: 1) no brome adjacent to the alfalfa plant (0% brome), 2) brome adjacent to the alfalfa crown for about 1/3 of its circumference (33%), 3) brome around 2/3 of the circumference of the alfalfa plant (66%), and 4) the entire plant was surrounded by brome which had intermingled with alfalfa stems (100%). Stems were cut at the crown and bagged. Eggs were recovered using the blender method as described by Pass & VanMeter (1966).

Larvae were collected 26 March, 1992 using the same sampling levels of weed interference as were used in egg sampling. Ten alfalfa stems were pulled in each microhabitat and cultivar. Larvae were retrieved with standard Berlese funnels and instars were determined by head capsule size.

Experiment II. The effect of downy brome densities on parasitism of the alfalfa weevil by *Bathyplectes* spp. was determined by rearing weevil larvae collected by sweeping on 09 April, 1992. Sweep samples were taken in each of the four replicates from subplots with high (no herbicide) and low (herbicide) levels of weed infestation in each cultivar. Subsamples of 150 larvae were reared on fresh alfalfa in 0.5L (1 pint) carton. Fresh alfalfa foliage was placed in the carton daily until all weevil larvae had pupated. After an additional period of about 2 weeks, alfalfa weevil adults and parasite cocoons were counted in each sample to determine percent parasitism.

Statistical Analysis

Experiment I Alfalfa weevil egg and larval data were subjected to regression analysis (SAS Institute 1991). Dummy variables were used to represent cultivars with numeric values in order to test differences in slopes ($\alpha = 0.05$) for each in the regression analysis. To determine if any differences in egg and larval numbers were

attributable to cultivar, regression lines were fitted for each cultivar over weed interference levels using the model given below:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + e_i,$$

where

Y = the number of alfalfa weevil eggs per plant or larvae per 10 stems,

X_1 = level of weed interference

X_2 = weed interference for 'OK08' alone

X_2 = wd * dv (weed interference x dummy variable)

dv = 1 for 'OK08' and 0 for 'Cimarron'

Based on the outcome of this regression analysis, data were reanalyzed if no significant differences in weevil numbers were detected between cultivars. A new model to predict egg and larval numbers versus weed interference was used:

$$Y = \beta_0 + \beta_1 X_1 + e_i$$

where

Y = the number of alfalfa weevil eggs per plant or larvae per 10 stems

X_1 = level of weed interference

Experiment II Data were subjected to a test of proportions for each cultivar and level of weed interference (Steel & Torrie 1980) and reported as the mean rate of parasitism per sample.

Results

Experiment I. The first model did not detect any significant differences in alfalfa weevil egg numbers among levels of weed interference levels ($t = -0.028$; $df = 1,62$; $P > 0.05$) or for weed interference x cultivars ($t = 1.329$; $df = 1,62$; $P > 0.05$). Also the model did not explain a significant amount of the variation in the numbers of weevil eggs observed ($r^2 = 0.039$). The estimated parameters for the model were:

$$\hat{Y} = 24.225 - 0.003X_1 - 0.112X_2.$$

Similar results occurred for the estimates of the parameters in the second model. The estimated slope for weed number in a linear regression model was not significantly different from zero ($t = -0.823$; $df = 1,62$; $P > 0.05$) and the amount of variation explained by the model was small ($r^2 = 0.011$) (Figure 1). The estimates for the parameters of the model were:

$$\hat{Y} = 24.221 - (0.058)X_1.$$

Applying the first model to the larval data, weed interference ($t = -1.374$; $df = 62$; $P > 0.05$) or weed interference x cultivar ($t = -0.814$; $df = 62$; $P > 0.05$) were not significant. The model explained little of the variation of the numbers of alfalfa weevil larvae observed ($r^2 = 0.0761$). The estimate for the parameters of the model were:

$$\hat{Y} = 243.128 + 0.076X_1 + 0.078X_2.$$

Data were reanalyzed using the second model. Although the model only explained a small amount of the variation in the numbers of larvae ($r^2 = 0.066$) (Figure 2), the estimated slope for weed numbers in a linear regression model was significantly different from zero ($t = -2.094$, $df = 1,62$; $P < 0.05$). The estimates for the parameters of the model were:

$$\hat{Y} = 24.221 - 0.058X_1.$$

Experiment II. Percentage parasitism by *Bathyplectes* spp. was not significantly different between cultivars ($z = 1.33418$; $P > 0.05$), but was significantly different between weed interference levels ($z = -4.398861$; $P > 0.05$). The percentage for samples from subplots highly infested with downy brome was 40.3%, while the rate increased to 50.6% for samples without brome (Figure III). *B. anurus* accounted for 3% of the parasites retrieved while the remainder were *B. curculionis*.

Discussion

Egg numbers in microhabitats with higher levels of brome interference were not significantly different from microhabitats with less brome interference. Although differences were quite small, more larvae were found in microhabitats with less downy brome interference than in microhabitats with more brome. Similarly, larval numbers in the Egyptian alfalfa weevil (*Hypera brunneipennis* Bohman) were reduced in plots heavily infested with winter annual weeds (Norris et al. 1984). In contrast, Wolfson & Yeargan (1983) found lower larval numbers in plots with fewer weeds. Dowdy (1988) found that larval numbers per stem were not correlated with the percent weed content of forage or alfalfa stand density.

Percentage parasitism by *Bathyplectes* spp. was greater in plots without downy brome interference (herbicide treated) than in those heavily infested with brome. One explanation for this difference may be the behavior of parasites seeking first the host plant then searching to locate the herbivore. Downy brome may decrease the searching ability of *Bathyplectes* spp. by interfering with its normal searching patterns. *Bathyplectes* spp. apparently thoroughly search alfalfa plants once they are located to find the weevil larvae.

More parasitism by *B. curculionis* than *B. anurus* was expected because sampling was conducted when the second generation *B. curculionis*, was prevalent while *B. anurus* populations were on the decline. Occurrence of parasitism by these species agrees with Berberet et al. (1978) who reported *B. curculionis* was more abundant than *B. anurus* in late April and May.

In conclusion alfalfa weevil egg densities per alfalfa plant were not influenced by increased downy brome interference in microhabitats. Slightly different indications were evident for larvae numbers which appeared to be reduced in microhabitats with increased levels of downy brome. Prevalence of parasitism of weevil larvae by *Bathyplectes* spp. was also greater in plots with little or no downy brome interference.

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APPENDIX A

TABLES FOR CHAPTER II

TABLES I - XIII

TABLE I

ALFALFA WEEVIL EGG NUMBERS ($\bar{X} \pm \text{SE}$) WITH THREE
GRAZING TREATMENTS, CHICKASHA, OK 1990-1992 ^a

Grazing Treatment	Sampling Date		
	04 Jan 1990	28 Feb 1991	05 Feb 1992
Extended-Grazing	91.0 \pm 11.6b	4.8 \pm 3.0a	26.2 \pm 6.2b
Flash-Grazing	48.0 \pm 4.9b	4.2 \pm 1.7a	60.7 \pm 12.1b
Ungrazed	132.7 \pm 16.8a	17.7 \pm 8.0a	116.7 \pm 19.0a
LSD	20.2	N.S.	43.7

^a Values in table are eggs per 0.1 m²

Means within each column with the same letter are not significantly different at $\alpha = 0.05$ (LSD test)

TABLE II
ALFALFA WEEVIL LARVAL NUMBERS ($\bar{X} \pm SE$) AS INFLUENCED
BY PESTICIDE TREATMENTS, CHICKASHA, OK 1990-1991

Pesticide Treatment	Larvae per 25 stems	
	05 April 1990	06 April 1991
Herbicide + Insecticide	$2.7 \pm 0.5b$	$7.4 \pm 1.4b$
Herbicide	$16.3 \pm 1.8a$	$19.9 \pm 3.6a$
Insecticide	$3.5 \pm 0.8b$	$6.5 \pm 1.6b$
Unsprayed	$16.0 \pm 1.9a$	$20.7 \pm 3.6a$
LSD	3.5	6.9

Means for each column with the same letter are not significantly different at $\alpha = 0.05$ (LSD test).

TABLE III

ANALYSIS OF VARIANCE (F STATISTIC) FOR ALFALFA STEMS PER 0.1 m²
CHICKASHA, OK 1990-1992

Source	df	F Statistics		
		22 March 1990	28 March 1991	26 March 1992
Grazing	2,6	2.00	7.03*	0.69
Cultivar	1,63	12.34*	11.20*	102.99*
Pesticide	3,63	0.21	2.66	4.68*

* Significant at $\alpha = 0.05$

TABLE IV

ALFALFA STEM NUMBERS ($\bar{X} \pm \text{SE}$) FOR FOUR PESTICIDE
TREATMENTS AND TWO CULTIVARS, CHICKASHA, OK 1990-1992

Treatment	Stems / 0.1 m ²		
	22 March 1990	28 March 1991	26 March 1992*
Herbicide + Insecticide	40.7 \pm 1.3a	18.0 \pm 0.5a	11.3 \pm 0.5a
Herbicide	40.8 \pm 1.2a	18.0 \pm 0.5a	9.8 \pm 0.5b
Insecticide	41.0 \pm 1.1a	19.1 \pm 0.5a	10.3 \pm 0.4ab
Unsprayed	39.7 \pm 1.1a	17.2 \pm 0.5a	9.1 \pm 0.5b
LSD	N.S.	N.S.	1.2
OK08	38.3 \pm 0.8b	17.3 \pm 0.6b	7.9 \pm 0.3b
Cimarron	42.8 \pm 0.9a	18.8 \pm 0.7a	12.3 \pm 0.3a
LSD	2.5	0.9	1.2

* Means for each column with the same letter are not significantly different at $\alpha = 0.05$ (LSD test).

TABLE V

ALFALFA STEM NUMBERS ($\bar{X} \pm \text{SE}$) AS INFLUENCED BY THREE
GRAZING TREATMENTS, CHICKASHA, OK 1990-1992

Grazing Treatment	Stems / 0.1 m ²		
	22 March 1990	28 March 1991*	26 March 1992
Flash-grazing	37.80 \pm 0.10a	19.70 \pm 0.40a	9.80 \pm 0.04a
Extended-grazing	40.70 \pm 0.10a	15.50 \pm 0.40b	10.30 \pm 0.04a
Ungrazed	43.40 \pm 0.10a	19.70 \pm 0.40a	10.20 \pm 0.04a
LSD	N.S.	2.9	N.S.

* Means for each column with the same letter are not significantly different at $\alpha = 0.05$ (LSD test).

TABLE VI
ANALYSIS OF VARIANCE (F STATISTICS) FOR ALFALFA YIELD
CHICKASHA, OK 1990-1992

Date	F Statistics		
	Grazing (2,6 df)	Cultivar (1,63 df)	Pesticide (3,63 df)
1990			
14 May	9.82*	60.45*	26.28*
12 June	0.17	0.37	0.75
Yearly Total	0.36	4.23*	8.09*
1991			
30 April	15.99*	38.90*	15.10*
05 June	2.6	10.25*	5.18*
Yearly Total	21.04*	10.94*	3.24
1992			
18 May	9.98*	107.94*	21.71*
13 July	2.65	121.19*	3.59*
Yearly Total	2.34	160.23*	6.40*

* Significant at $\alpha = 0.05$

TABLE VII

ALFALFA PRODUCTION (KG/HA) ($\bar{X} \pm SE$) AS INFLUENCED
BY GRAZING TREATMENTS, CHICKASHA, OK 1990-1992

Harvest Date	Extended-grazing	Flash-grazing	Ungrazed
1990			
14 May	2,338 \pm 76b	3,201 \pm 75a	2,716 \pm 79b
13 June	3,948 \pm 102a	3,883 \pm 153a	3,886 \pm 108a
1991			
30 April	2,011 \pm 58b	2,658 \pm 53a	2,462 \pm 69a
05 June	3,408 \pm 63a	3,598 \pm 57a	3,442 \pm 75a
1992			
18 May	2,045 \pm 83a	1,728 \pm 91b	1,685 \pm 95b
13 July	2,323 \pm 101a	2,144 \pm 120a	2,336 \pm 106a

Means within each row with the same letter are not significantly different at $\alpha = 0.05$ (LSD test)

TABLE VIII

ALFALFA FORAGE PRODUCTION (KG/HA) ($\bar{X} \pm \text{SE}$) FOR PESTICIDE
TREATMENTS AND CULTIVARS, CHICKASHA, OK 1990

Treatment	14 May	13 June
Herbicide + Insecticide	3,392 \pm 69a	4,048 \pm 114a
Herbicide	3,108 \pm 72b	3,927 \pm 141a
Insecticide	2,633 \pm 79c	3,799 \pm 117a
Unsprayed	2,540 \pm 103c	3,848 \pm 184a
LSD	222	353
Cimarron	3,223 \pm 56a	3,943 \pm 84a
OK08	2,613 \pm 63b	3,867 \pm 113a
LSD	157	250

Means with the same letter for each column are not significantly different $\alpha = 0.05$
(LSD test)

TABLE IX

YEARLY ALFALFA PRODUCTION (KG/HA) ($\bar{X} \pm SE$) FOR GRAZING
SCHEDULES, PESTICIDE TREATMENTS, AND CULTIVARS,
CHICKASHA, OK 1990-1992

Treatment	1990	1991	1992
Flash-Grazing	12,895 \pm 46a	14,301 \pm 58a	8,703 \pm 88a
Extended-Grazing	12,603 \pm 43a	12,279 \pm 81b	9,372 \pm 94a
Ungrazed	12,817 \pm 46a	14,021 \pm 36a	9,242 \pm 84a
LSD	N.S.	827	N.S.
Herbicide + Insecticide	13,587 \pm 53a	14,117 \pm 45a	9,829 \pm 120a
Herbicide	12,844 \pm 54b	13,406 \pm 128ab	9,305 \pm 114a
Insecticide	12,563 \pm 55bc	13,936 \pm 72a	9,417 \pm 91a
Unsprayed	12,092 \pm 62c	12,676 \pm 69b	7,871 \pm 113b
LSD	622	717	953
Cimarron	12,998 \pm 25a	14,127 \pm 47a	11,241 \pm 49a
OK08	12,545 \pm 33b	12,940 \pm 78b	6,971 \pm 24b
LSD	440	1014	674

Means within each column with the same letter are not significantly different at $\alpha = 0.05$ (LSD test)

TABLE X

ALFALFA FORAGE PRODUCTION (KG/HA)($\bar{X} \pm SE$) FOR PESTICIDE
TREATMENTS AND CULTIVARS, CHICKASHA, OK 1991

Treatment	30 April	05 June
Herbicide + Insecticide	2,659 \pm 61a	3,641 \pm 76a
Herbicide	2,430 \pm 81b	3,321 \pm 102b
Insecticide	2,425 \pm 76b	3,600 \pm 73a
Unsprayed	1,993 \pm 83c	3,369 \pm 85b
LSD	202	200
Cimarron	2,598 \pm 55a	3,596 \pm 55a
OK08	2,156 \pm 53b	3,369 \pm 66b
LSD	143	141

Means with the same letter for each column are not significantly different $\alpha = 0.05$
(LSD test)

TABLE XI

ALFALFA WEEVIL LARVAL NUMBERS PER 25 STEMS ($\bar{X} \pm \text{SE}$) AS INFLUENCED BY GRAZING, PESTICIDES, AND CULTIVARS, CHICKASHA, OK, 30 MARCH 1992

Treatment	Extended-Grazing	Flash-Grazing	Ungrazed
Herbicide + Insecticide	33.3 \pm 4.4d	37.1 \pm 7.0c	30.9 \pm 4.0b
Herbicide	79.8 \pm 12.0b	59.0 \pm 9.4b	78.1 \pm 5.6a
Insecticide	55.9 \pm 7.8c	48.8 \pm 4.8b	29.3 \pm 6.6b
Unsprayed	103.6 \pm 11.2a	87.8 \pm 11.6a	76.9 \pm 10.6a
LSD	20.8	14.2	16.4
Cimarron	73.4 \pm 8.7a	67.7 \pm 8.7a	60.4 \pm 9.2a
OK-08	62.8 \pm 9.7a	48.6 \pm 5.4b	47.1 \pm 5.6b
LSD	N.S.	10.0	11.6

Means with the same letter for each column are not significantly different $\alpha = 0.05$ (LSD test)

TABLE XII

ALFALFA FORAGE PRODUCTION (KG/HA)($\bar{X} \pm SE$) FOR PESTICIDE
TREATMENTS AND CULTIVARS, CHICKASHA, OK 1992

Treatment	18 May	13 July
Herbicide + Insecticide	2,218 \pm 98a	2,672 \pm 140a
Herbicide	2,106 \pm 110a	2,531 \pm 166ab
Insecticide	1,654 \pm 88b	2,564 \pm 117ab
Unsprayed	1,299 \pm 88c	2,401 \pm 145b
LSD	257	257
Cimarron	2,291 \pm 64a	3,042 \pm 53a
OK08	1,347 \pm 62b	2,041 \pm 83b
LSD	182	182

Means with the same letter for each column are not significantly different
 $\alpha = 0.05$ (LSD)

TABLE XIII

DOWNY BROME PLANT POPULATIONS ($\bar{X} \pm \text{SE}$) AS INFLUENCED
BY PESTICIDE TREATMENTS AND CULTIVARS,
CHICKASHA, OK 1992

Treatment	Plants per 0.1m ²
Herbicide + Insecticide	0.3 \pm 0.1c
Herbicide	0.3 \pm 0.1c
Insecticide	1.6 \pm 0.1b
Unsprayed	2.3 \pm 0.1a
LSD	0.4
Cimarron	0.9 \pm 0.1b
OK08	1.4 \pm 0.1a
LSD	0.3

Means with the same letter for each column are not significantly different
 $\alpha = 0.05$ (LSD)

APPENDIX B

TABLES FOR CHAPTER III

TABLES XIV - XX

TABLE XIV

EARLY SEASON ALFALFA STEM COUNTS ($\bar{X} \pm SE$) PER 0.1 m²,
CHICKASHA, OK 1990-1992

Weed Infestation	High Weevil #s	Low Weevil #s	T test ^a
26 March 1990			
Warm + Cool Grasses	29.5 \pm 0.8	35.6 \pm 2.9	P = 0.35
Warm Grasses	33.1 \pm 0.9	39.5 \pm 2.1	P = 0.20
Cool Grasses	30.0 \pm 0.9	37.1 \pm 0.9	P = 0.10
No Grasses	36.0 \pm 1.6	38.1 \pm 0.8	P = 0.57
LSD	N.S.	N.S.	
28 March 1991			
Warm + Cool Grasses	17.7 \pm 0.6	17.2 \pm 0.6	P = 0.78
Warm Grasses	17.5 \pm 0.2	18.0 \pm 0.4	P = 0.68
Cool Grasses	19.4 \pm 0.6	16.2 \pm 0.4	P = 0.08
No Grasses	17.6 \pm 0.7	17.5 \pm 0.4	P = 0.75
LSD	N.S.	N.S.	
12 March 1992			
Warm + Cool Grasses	8.9 \pm 0.8	9.7 \pm 0.6	P = 0.08
Warm Grasses	9.9 \pm 0.6	9.1 \pm 0.6	P = 0.63
Cool Grasses	8.1 \pm 0.4	9.6 \pm 0.4	P = 0.18
No Grasses	8.8 \pm 0.8	10.9 \pm 0.6	P = 0.35
LSD	N.S.	N.S.	

* Means for each column with the same letter are not significantly different at $\alpha = 0.05$ (LSD test).

^a T tests compare alfalfa production for high weevil numbers vs. low weevil numbers given harvest and weed infestation

TABLE XV

ALFALFA PRODUCTION (KG/HA) ($\bar{X} \pm \text{SE}$) AS INFLUENCED BY ALFALFA WEEVIL INFESTATION AND WEED INTERFERENCE, CHICKASHA, OK 1990

Weed Infestation	High Weevil #s	Low Weevil #s	T test ^a
First Harvest (15 May)			
Warm + Cool Grasses	1,881 \pm 285c	2,156 \pm 343bc	P = 0.76
Warm Grasses	2,944 \pm 244a	2,994 \pm 343ab	P = 0.89
Cool Grasses	1,998 \pm 274bc	1,846 \pm 172c	P = 0.59
No Grasses	2,657 \pm 197ab	3,060 \pm 157a	P = 0.17
LSD	764	803	
Yearly Production			
Warm + Cool Grasses	9,683 \pm 205	9,830 \pm 420b	P = 0.56
Warm Grasses	10,608 \pm 515	10,506 \pm 482a	P = 0.91
Cool Grasses	9,405 \pm 663	9,008 \pm 311b	P = 0.66
No Grasses	9,682 \pm 413	10,547 \pm 377a	P = 0.10
LSD	N.S.	1,241	

* Means for each column with the same letter are not significantly different at $\alpha = 0.05$ (LSD test).

^a T tests compare alfalfa production for high weevil numbers vs. low weevil numbers given harvest and weed infestation

TABLE XVI

ALFALFA PRODUCTION (KG/HA) ($\bar{X} \pm SE$) AS INFLUENCED BY ALFALFA WEEVIL INFESTATION AND WEED INTERFERENCE, CHICKASHA, OK 1991.

Weed Infestation	High Weevil #s	Low Weevil #s	T test ^a
First Harvest (02 May)			
Warm + Cool Grasses	2,115 \pm 103	2,224 \pm 126	P = 0.35
Warm Grasses	1,845 \pm 262	2,439 \pm 141	P = 0.16
Cool Grasses	1,966 \pm 174	2,301 \pm 124	P = 0.75
No Grasses	2,389 \pm 134	2,709 \pm 295	P = 0.08
LSD	N.S.	N.S.	
Yearly Production			
Warm + Cool Grasses	13,868 \pm 780	14,625 \pm 170	P = 0.53
Warm Grasses	14,781 \pm 428	15,670 \pm 352	P = 0.09
Cool Grasses	14,876 \pm 1245	15,386 \pm 863	P = 0.17
No Grasses	14,886 \pm 442	17,291 \pm 1048	P = 0.36
LSD	N.S.	N.S.	

* Means for each column with the same letter are not significantly different at $\alpha = 0.05$ (LSD test).

^a T tests compare alfalfa production for high weevil numbers vs. low weevil numbers given harvest and weed infestation

TABLE XVII

ALFALFA PRODUCTION (KG/HA) ($\bar{X} \pm SE$) AS INFLUENCED BY ALFALFA WEEVIL INFESTATION AND WEED INTERFERENCE, CHICKASHA, OK 1992

Weed Infestation	High Weevil #s	Low Weevil #s	T test ^a
First Harvest (22 May)			
Warm + Cool Grasses	1,488 \pm 235	1,760 \pm 196	P = 0.14
Warm Grasses	1,521 \pm 246	1,878 \pm 281	P = 0.11
Cool Grasses	1,168 \pm 207	1,793 \pm 230	P = 0.00
No Grasses	1,396 \pm 257	1,835 \pm 209	P = 0.03
LSD	N.S	N.S	
Yearly Production			
Warm + Cool Grasses	8,930 \pm 646	10,038 \pm 348	P = 0.18
Warm Grasses	8,686 \pm 297	9,913 \pm 162	P = 0.14
Cool Grasses	10,290 \pm 1114	11,646 \pm 162	P = 0.29
No Grasses	10,035 \pm 1167	11,663 \pm 464	P = 0.24
LSD	N.S.	N.S.	

* Means for each column with the same letter are not significantly different at $\alpha = 0.05$ (LSD test).

^a T tests compare alfalfa production for high weevil numbers vs. low weevil numbers given harvest and weed infestation

TABLE XVIII

EARLY SEASON ALFALFA STEM COUNTS ($\bar{X} \pm \text{SE}$) PER 0.1 m²,
STILLWATER OK, 1991-1992.

Weed Infestation	High Weevil #s	Low Weevil #s	T test ^a
26 March 1991			
Warm + Cool Grasses	17.5 \pm 0.5	18.1 \pm 0.2	P = 0.56
Warm Grasses	17.3 \pm 0.4	17.4 \pm 0.2	P = 0.91
Cool Grasses	18.0 \pm 0.6	16.4 \pm 0.3	P = 0.25
No Grasses	17.7 \pm 0.4	17.0 \pm 0.3	P = 0.45
LSD	N.S.	N.S.	
30 March 1992			
Warm + Cool Grasses	8.6 \pm 0.3	13.5 \pm 0.4	P < 0.01
Warm Grasses	7.8 \pm 0.4	12.2 \pm 0.1	P < 0.01
Cool Grasses	8.8 \pm 0.2	10.9 \pm 0.8	P = 0.29
No Grasses	8.2 \pm 0.4	11.1 \pm 0.3	P = 0.04
LSD	N.S.	N.S.	

* Means for each column with the same letter are not significantly different at $\alpha = 0.05$ (LSD test).

^a T tests compare alfalfa production for high weevil numbers vs. low weevil numbers given harvest and weed infestation

TABLE XIX

ALFALFA PRODUCTION (KG/HA) ($\bar{X} \pm SE$) AS INFLUENCED BY ALFALFA WEEVIL INFESTATION AND WEED INTERFERENCE, STILLWATER, OK 1991

Weed Infestation	High Weevil #s	Low Weevil #s	T test ^a
First Harvest 01 May			
Warm + Cool Grasses	1,762 \pm 75b	2,354 \pm 247c	P = 0.56
Warm Grasses	2,172 \pm 98a	2,373 \pm 562a	P = 0.24
Cool Grasses	1,804 \pm 83b	2,369 \pm 86ab	P = 0.21
No Grasses	1,880 \pm 170ab	2,360 \pm 198ab	P = 0.18
LSD	348	N.S.	
Yearly Production			
Warm + Cool Grasses	8,716 \pm 412	9,118 \pm 502	P = 0.56
Warm Grasses	9,047 \pm 218	9,623 \pm 382	P = 0.25
Cool Grasses	8,486 \pm 176	9,042 \pm 358	P = 0.21
No Grasses	8,276 \pm 317	9,194 \pm 515	P = 0.17
LSD	N.S.	N.S.	

* Means for each column with the same letter are not significantly different at $P > 0.05$ (LSD test).

^a T tests compare alfalfa production for high weevil numbers vs. low weevil numbers given harvest and weed infestation

TABLE XX

ALFALFA PRODUCTION (KG/HA) ($\bar{X} \pm SE$) AS INFLUENCED BY ALFALFA WEEVIL INFESTATION AND WEED INTERFERENCE, STILLWATER, OK 1992

Weed Infestation	High Weevil #s	Low Weevil #s	T test ^a
First Harvest 30 April			
Warm +Cool Grasses	88 \pm 65c	1,504 \pm 115c	P = 0.07
Warm Grasses	616 \pm 232a	2,157 \pm 114a	P = 0.01
Cool Grasses	167 \pm 108c	1,764 \pm 158ab	P = 0.04
No Grasses	500 \pm 234ab	1,951 \pm 65ab	P = 0.03
LSD	172	362	
Yearly Production			
Warm + Cool Grasses	6,005 \pm 556	9,065 \pm 1190	P > 0.01
Warm Grasses	5,601 \pm 596	8,961 \pm 564	P > 0.01
Cool Grasses	6,774 \pm 556	8,881 \pm 604	P > 0.010
No Grasses	7,080 \pm 445	10,539 \pm 1045	P > 0.01
LSD	N.S.	N.S.	

* Means for each column with the same letter are not significantly different at P > 0.05 (LSD test).

^a T tests compare alfalfa production for high weevil numbers vs. low weevil numbers given harvest and weed infestation

APPENDIX C

FIGURES FOR CHAPTER IV

alfalfa weevil eggs / plant

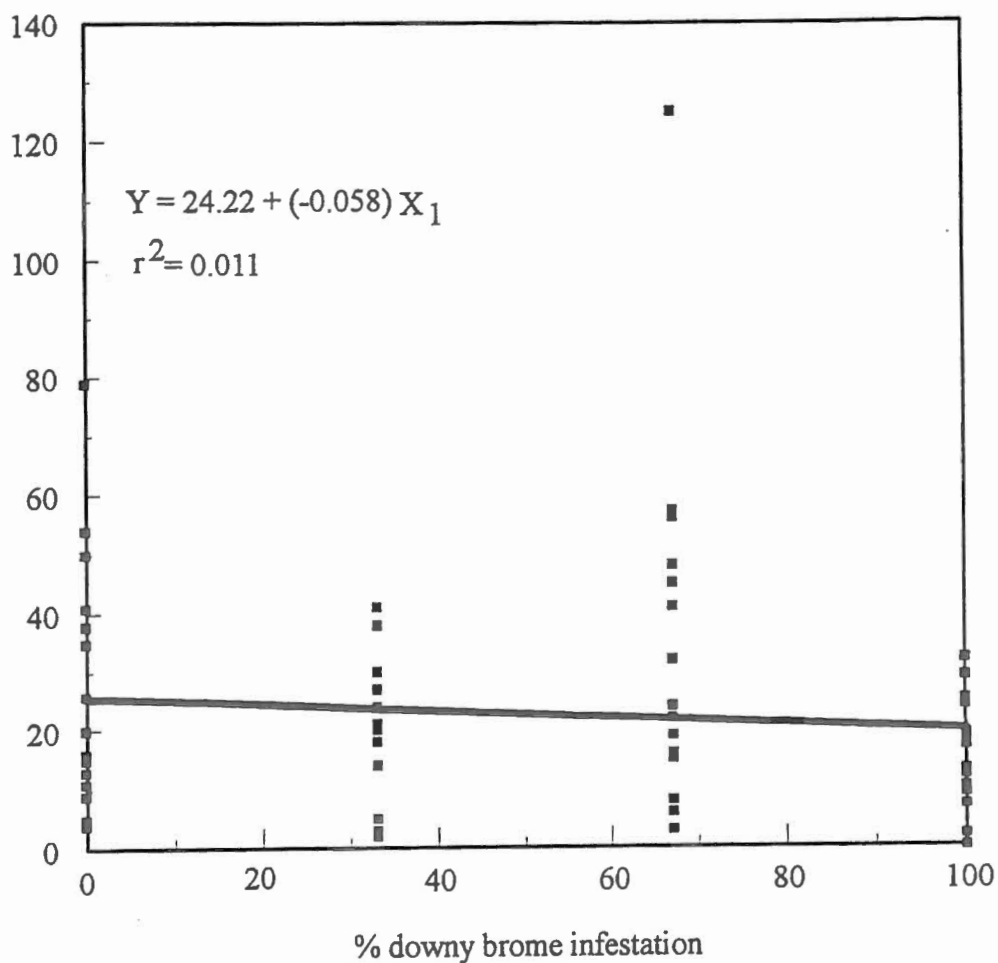


Figure 1. Relationship of alfalfa weevil egg numbers and extent of downy brome infestation adjacent to alfalfa plants. (Percentages reflect amount of area around alfalfa plants occupied by downy brome).

alfalfa weevil larvae / 10 stems

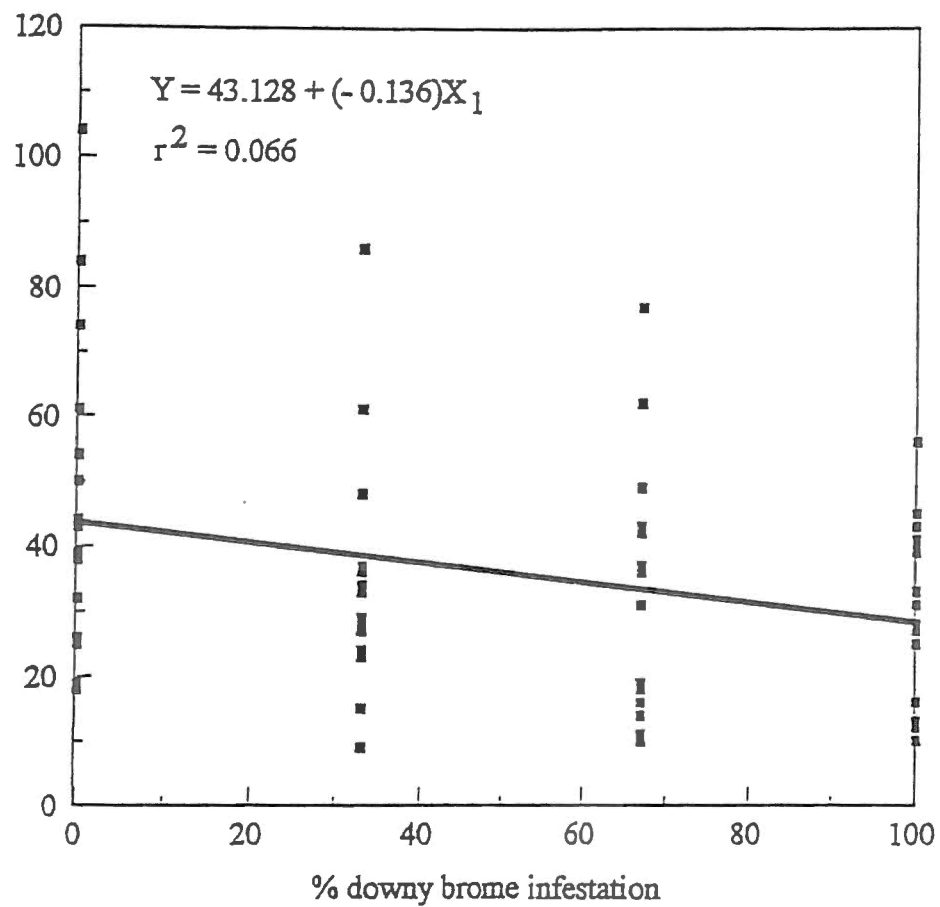
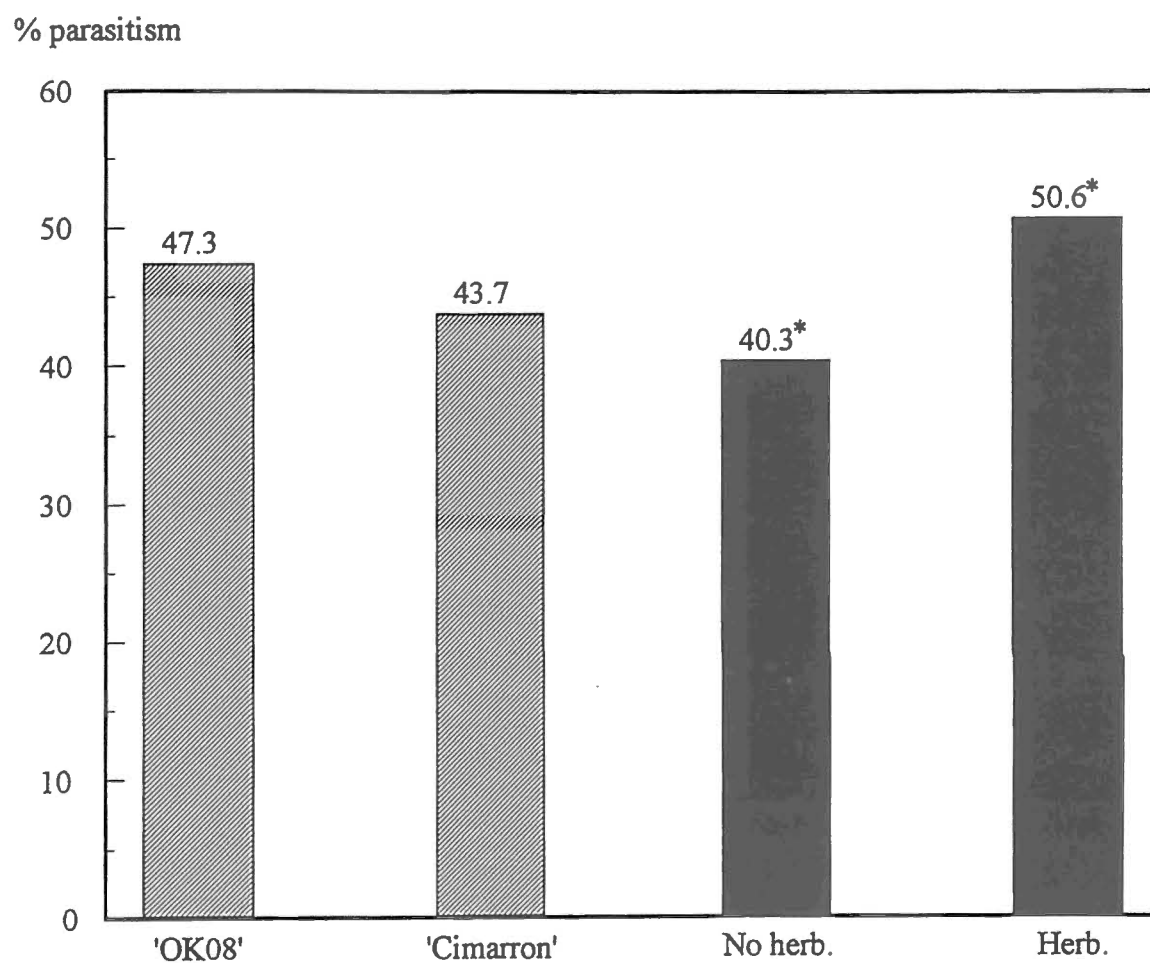


Figure 2. Relationship of alfalfa weevil larval numbers and extent of downy brome infestation adjacent to alfalfa plants. (Percentages reflect amount of area around alfalfa plants occupied by downy brome)



* Weed numbers: $Z = 4.398$; $P < 0.05$

Cultivar: $Z = 1.3348$; $P > 0.05$

Figure 3. Parasitism of alfalfa weevil larvae by *Bathyplectes* spp. as influenced by alfalfa cultivars and extent of downy brome infestation

VITA

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Candidate for the Degree of

Master of Science

These: ALFALFA PRODUCTIVITY WITH VARYING LEVELS OF ALFALFA
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